

## **NMFS SWFSC Report (March 2021): Thiamine Deficiency in West Coast Salmon**

### **PURPOSE**

Thiamine Deficiency Complex (TDC) was first documented in California's salmon in 2020 with continuing impacts to Central Valley spring-run, fall run, late fall, and winter run. Hatchery staff noticed offspring swimming in circles and dying at elevated rates. They traced the condition to a deficiency of thiamine, or vitamin B1, passed on from the returning adults to their offspring. Juvenile hatchery salmon were quickly revived following treatment in thiamine baths, yet this treatment may mask irreversible health impacts due to low thiamine during embryo development. Impacts to naturally spawning populations remain the greatest unknown and could be an unrecognized factor affecting harvest opportunities and impede salmon recovery.

### **FOUR THINGS YOU MUST KNOW**

- **Rapid-Response Research:** Investigations by Southwest Fisheries Science Center (SWFSC), CDFW's Fish Production and Aquatic Pathology staff, Ocean Salmon Project staff, and other partners are underway to understand the extent, cause and effects of TDC on Central Valley Chinook salmon, as well as potential treatment. Scientists hypothesize that Central Valley Chinook salmon fed heavily on a narrow diet of northern anchovy concentrated off the central California Coast. Anchovies produce an enzyme called thiaminase that breaks down thiamine in salmon, and is suspected of contributing to TDC. While the cause of TDC may be linked to the ocean food web, it can have significant impacts to salmon productivity in the freshwater and hatchery mitigation goals.
- **Results To Date:**
  - **Improved Survival:** Injecting endangered winter-run Chinook salmon females with thiamine months prior to spawning significantly improved survival of their young. Over half of the untreated winter run showed TDC. On-going research is investigating the short-term vs. long-term gains of thiamine treatment at different life stages in hatcheries for the different salmon runs (egg, fry, adults).
  - **Critical Thresholds:** Researchers have identified the critical threshold level of egg thiamine (>5nmol/g) whereby TDC does not occur.
  - **2020 Stock Susceptibility Index:** Surveillance of eggs in hatcheries shows some stocks in 2020 were more susceptible to TDC than others (CV late fall, winter run, and spring run), but this may change in different years.
  - **Collaborators:** Commercial and recreational fishermen are engaged in providing salmon stomachs and tissues to reconstruct salmon diets. Teachers participating in CDFW's Salmon in the Classroom program have observed TDC and we are developing citizen science opportunities from the data they are collecting and curriculum related to thiamine deficiency.

- Potential Implications of TDC:** While not all stocks are likely to be affected by TDC similarly, if ESA-listed stocks are significantly impacted by TDC as observed in 2020, this may have implications for recreational and commercial fisheries that are constrained by the status of sensitive stocks (i.e., winter-run Control Rule). Early life stage mortality and latent effects associated with TDC in naturally produced salmonids are difficult to detect. This reduction in juvenile production may be mistakenly attributed to other factors such as flows, temperatures, or habitat availability. The results of monitoring intended to assess the success of a restoration program or reintroduction may be skewed if TDC-related impacts go undetected. Water operations and associated take authorizations (CVP/SWP) that are based on the annual winter-run Chinook salmon juvenile production estimate (JPE) may also be impacted.

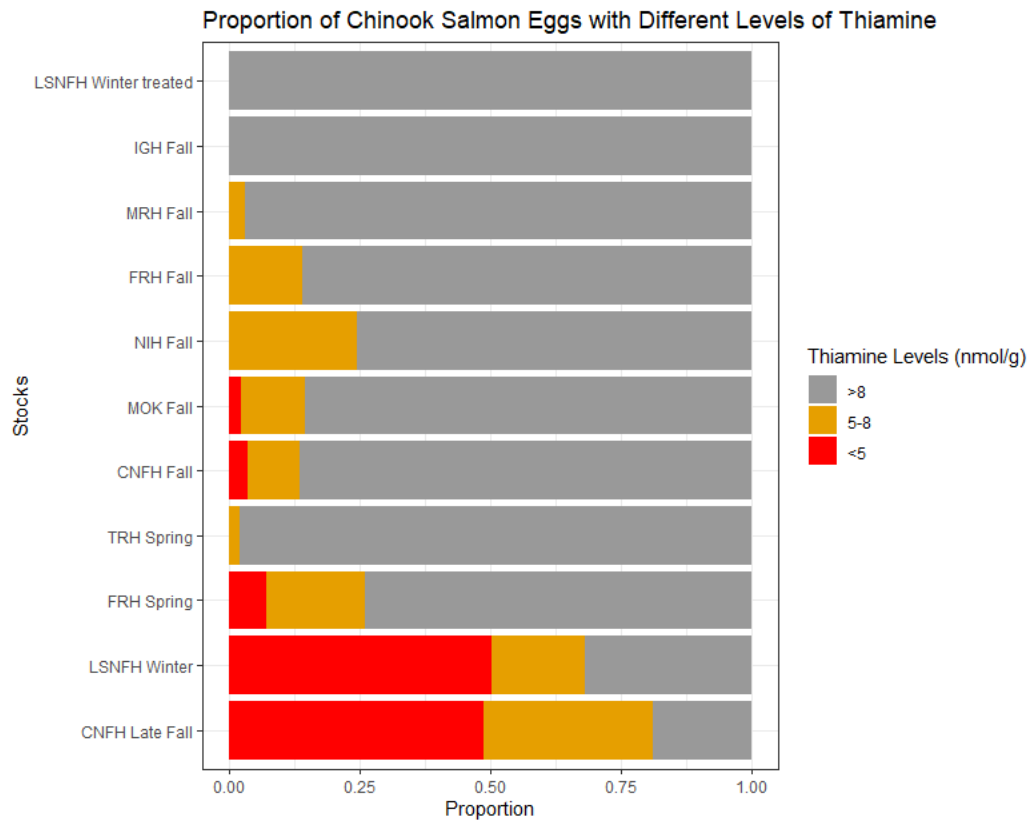


Fig. 1 Proportion of Chinook salmon (N=30 per stock) in 2020 that had high (>8 nmol/g), intermediate (5-8 nmol/g), and low (<5 nmol/g) egg thiamine levels. Note: General order of timing of ocean exit of stocks from earliest (bottom) to most recent (top) with coastal salmon stocks included (TRH Spring and IGH Fall).

## **BACKGROUND**

In early 2020 staff at several salmon hatcheries in California’s Central Valley noticed the offspring of recently returned adult Chinook salmon swimming in circles and dying at elevated rates. There were also reports of high mortality among naturally spawned juveniles in some Central Valley rivers. Hatchery staff traced the condition to a deficiency of thiamine, or vitamin B1, passed on from the adult fish to

juveniles. Juvenile hatchery salmon improved in condition almost immediately following treatment in thiamine baths. No treatment of naturally spawned fish in rivers was possible. Total fry mortality in fall-run Chinook salmon in Central Valley hatcheries in 2020 is estimated at about 5 percent (after thiamine bath treatments), although previous work suggests treatment cannot reverse effects of compromised immunity. The magnitude of mortalities of naturally spawned juveniles remains unclear. However, reports indicate it could be substantial in some areas and affecting stocks of harvest value and those of conservation concern. The only other report of TDC in 2020 came from one group of hatchery-origin coho salmon juveniles at Iron Gate Hatchery in the Klamath River Basin.

### **PREVIOUS EVIDENCE**

Although previous data indicates that at least some Pacific Coast salmon may have been affected by thiamine deficiency before, more information is available from other parts of the world. Thiamine deficiency affecting Atlantic salmon and other fish and wildlife in the Baltic Sea is so well known that it is called thiamine deficiency syndrome, or syndrome M74, and is responsible for reduced reproduction. Thiamine deficiency has also been documented in Lake Trout and introduced Pacific salmon (Chinook salmon, coho salmon, Atlantic salmon, and steelhead) in the Great Lakes. An investigation by the Alaska Department of Fish and Game of low returns of Chinook salmon to the Yukon River found that a majority of eggs tested in 2014 and 2015 had levels of thiamine low enough to cause sub-lethal effects likely to compromise the population's productivity.

### **OCEAN CONDITIONS**

Marine surveys off the West Coast in 2019 found the highest abundances of northern anchovy off Central and Southern California since systematic surveys began in 1983. The 2019 annual report of the California Cooperative Oceanic Fisheries Investigations called it a "novel anchovy regime."<sup>1</sup> In 2019, other typical salmon prey such as krill fell to unusually low levels, and reports from fishermen indicated salmon off central California fed almost exclusively on northern anchovy in the months before returning to their home rivers.

While ocean surveys were sharply limited in 2020 due to COVID concerns, limited survey trawls in the Gulf of the Farallones, sea bird diet observations, stomach contents from ocean caught Chinook salmon, and anecdotal reports from the fishing community all point to 2020 having an anchovy-dominated forage base off California's Central Coast (south of Pt. Arena). In 2021, we will analyze levels of thiamine, thiaminase, and stable isotopes in salmon prey collected in ocean surveys and fisheries to identify shifts in the marine food web and West Coast salmon distributions in 2019 and 2020 that may have contributed to TDC.

### **PROTECTING WINTER-RUN CHINOOK SALMON**

NMFS WCR authorized Livingston Stone National Fish Hatchery to collect up to 80 female and 160 male ESA endangered winter-run Chinook salmon, an increase over the standard annual collection of 60

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<sup>1</sup>Thompson, A., et al. 2019: State of the California Current 2018–19: a novel anchovy regime and a new marine heatwave? *Calcofi rep.*, vol. 60, p 1-65.

females and 120 males. The collection of additional adult winter-run Chinook salmon increased hatchery production, securing the species against TDC and anticipated adverse river conditions involving a limited supply of cold water in Shasta Reservoir to protect naturally spawned eggs and embryos in the Sacramento River. Some of the returning females collected at the hatchery received supplemental thiamine injections to determine whether that reduces ill-effects among their offspring. A control group was injected with saline for comparison. Injecting females significantly improved egg thiamine concentration ( $35.0 \pm 7.2$  nmol/g) and survival of progeny. Baseline levels of egg thiamine in untreated winter run were low ( $5.2 \pm 4.4$  nmol/g), resulting in 50% of their fry expressing TDC symptoms. This work allowed us to assess the effects of various thiamine levels on survival and health of their offspring with the ability to assess likely impacts of TDC for winter-run Chinook salmon spawning in the wild. Ongoing acoustic tagging studies will test for differences in survival of juveniles that were treated through maternal injections compared to later life stage treatment as fry as they migrate to the ocean.

### **STUDYING CALIFORNIA COASTAL POPULATIONS IN THE KLAMATH**

The SWFSC is working with CDFW in the Klamath Basin to determine if TDC is an issue for Pacific salmon and steelhead returning to Iron Gate (IGH) and Trinity River (TRH) hatcheries. Out of an abundance of caution, egg samples were collected from fall-run Chinook salmon and ESA-listed coho salmon from IGH and, ESA-listed coho salmon, and fall-run and spring-run Chinook salmon from TRH. In the coming months steelhead from TRH will also be collected. To date there is one report in 2020 of thiamine deficiency from a group of juvenile coho salmon at IGH. In addition to egg collection at the hatcheries, SWFSC is working with the Yurok Tribe to obtain egg samples from harvested Chinook salmon in the lower river throughout the Chinook salmon run in 2021. The goal is to determine whether TDC is an issue in the Klamath Basin which could be critical for informing current and future conservation and management decisions. The only coastal stocks we have egg thiamine data results for- IGH Fall and TRH Spring- both show elevated thiamine levels relative to Central Valley stocks. This is likely due to different ocean distributions and foraging areas.

### **POINTS OF CONTACT**

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